Substitute Paragraphs to Amend the Specification

[0027] In this manner, a very large fraction of the power delivered from the power supply to the circuit results in useable UWB RF energy at the output. Peak power output is only limited by the available current and voltage handling capacity of the switching device, which is typically tens of or even hundreds of watts.

[0030] Fig. 1 shows a normalized model of a singly terminated filter network 100 comprising a three-pole Chebyshev lowpass filter having a passband ripple of one decibel (1dB). Network 100 includes a current source 1, a 1.509 Farad shunt capacitor 2, a 1.33 Henry series inductor 3, a 1.012 Farad shunt capacitor ~~5,~~ 4, and a unitary impedance, e.g., a one-ohm output impedance 5. As developed in the following description, a filter network having a desired function is derived by scaling circuit components of model filter 100.

[0031] In the network 100, values of the inductive and capacitive components have been normalized such that the 1db ripple point occurs at a unitary measure of frequency, e.g., ~~1/(2P)~~ $1/(2\pi)$ Hertz. As driven by current source 1, the source termination impedance is infinite. However, the transfer function, defined herein as the ratio of the output voltage V across impedance 5 to the input current I of current source 1, has the desired Chebyshev response. Derivation of such a normalized model filter is covered in many texts, including the Zverev reference mentioned herein. The impulse response of model filter 100 is band-limited to produce a UWB signal when current source 1 comprises an impulse source.

[0032] In order to produce a band-limited UWB pulse having a particular power, spectral shaping, bandwidth and/or center-frequency, component values of model filter network 100 must be de-normalized. As an

example, to produce a band-limited UWB system having 30-50 MHz response, component values of the normalized filter network 100 are first scaled to provide a 20 MHz bandwidth (using, for example, a 50% fractional bandwidth to define limits of the frequency band). This involves dividing all inductances and capacitances of the normalized filter network 100 by ~~2P~~ 2π x (20 x 10^6). Thus, the scaled values of capacitors 2 and 4 become 12.0 and 8.05 nanofarads (nF), and the value of inductor 3 becomes 10.6 nanohenrys (nH). Fig. 2 depicts corresponding circuit elements (i.e., capacitors 6 and 10, as well as inductor 9) having such scaled values.

[0034] To derive a filter network 300 of Fig. 3 that accommodates a 50-ohm output impedance instead of the normalized value of ~~1 W~~ 1 Ω, e.g., an impedance ratio of 50, component values of network 200 of Fig. 2 were further scaled. As an initial estimate, inductor values are multiplied by the impedance ratio (50 in this case) and capacitor values are divided by the same impedance ratio. The current source has been replaced by transistor 12, which, in the illustrated embodiment, comprises an MRF166C field effect transistor. Since the output capacitance of a typical MRF166C transistor is approximately 30pF, this amount was subtracted from the estimated 240 picofarad scaled value of capacitor 13, i.e., 12nF value of capacitor 6 (Fig. 2) divided by 50 equals 240 picofarads, less 30 picofarad parasitic capacitance of transistor 12, yields a value of 210 picofarads for capacitor 12 in the scaled circuit 300. As such, the parasitic capacitance of the current source becomes integrated with the filter network to attain a desired resonance in accordance with an aspect of the present invention.

[0036] Filter network 300 is operated by delivering a short pulse to the gate of transistor 12 to release a corresponding short burst of energy across the transistor source/drain terminals and into the resonant filter network.

During the resulting short conduction cycle, drain current of transistor 12 rises roughly linearly with time through inductor 14. If the drain current is limited to four amperes by controlling the duration of a gate pulse, energy stored in inductor ~~13~~ 14 is calculated to be approximately 530 nanoJoules (nJ). The time taken to reach this level is about 9.5 nanoseconds (ns), which is relatively short compared to the UWB pulse duration (roughly 50 ns for a 20 MHz bandwidth waveform). Thus, transistor 12 forms a good approximation of a current source impulse generator as the conduction path therein is pinched off and of substantially high impedance during a majority of the time of network resonance. In this example, the filter network 300 resonates for more than 50ns after the onset of impulse excitation, during which time transistor 12 is turned off. Note that transistor 12 is intended to be operated as a switch, and so it operates in a highly nonlinear mode.

[0037] In practice, for such short duration pulses, most transistors can be operated at significantly higher current levels than specified by their maximum ratings. This is due to the fact that deleterious heating effects are minimized through the use of short pulses. For example, as much as eight amperes may be drawn through an MRF166C transistor for short time periods at a single time instance or at multiple, repetitive time instances. As such, it has been found that significantly more power can be delivered by the filter network 300 without damaging transistor 12 by scaling the network impedance down to ~~25 W~~ 25 Ω. Furthermore, the energy stored in capacitor 13 of network 300 can be significant. As described to this point, that energy is completely lost or dissipated in transistor 12 when turned on. Charge stored in capacitor 13 contributes to the drain current of transistor 12 but does nothing useful.

[0038] Fig. 4A shows an improved, high-power filter network 400 that achieves greater than 50% power efficiency. Relative to the circuit of Fig. 3,

circuit components of Fig. 4A have been further scaled to match the output impedance of ~~25W~~ 25Ω load 26. By scaling the filter network 300 to match the twenty-five ohm output impedance, the 66hH value of inductor 14 (Fig. 3) becomes 33nH in Fig. 4A. In accordance with another aspect of the present invention, however, the corresponding inductor 14 (Fig. 3), when designing the filter network 400 of Fig. 4A, is split into two inductor sections 14a and 14b of 29nH and 6nH, respectively. Parametric values of other circuit components have also been scaled in Fig. 4A. When scaled, the values of capacitors 21, 22, and 24 of network 400 become 450pF, 64pF, and 320pF, respectively. The values of inductors 23 and 25 become 265nH and 52nH, respectively.

[0040] Fig. 4B shows computer simulated waveforms of a gate signal 27 as well as the current I flowing through and the voltage V appearing at the drain terminal 20a of transistor 20 of filter network 400 (Fig. 4A). Due to a carefully chosen resonance condition, the currents in inductor section 14a and 14b substantially cancel, causing current flow I through transistor 20 to drop to very near zero at point 28 after a short time period, e.g., about 8.5 nsec after falling edge 27a of gate pulse 27. By turning off switching device 20 at this point in time, as indicated by the rising edge 29 of gate signal 27 (at or near when voltage V begins cycling), essentially no abrupt change in inductor current occurs in either inductor 14a or 14b. As a result, there is no substantial voltage spike on switching device 20 at this point. This serves not only to protect transistor 20 from potentially damaging output voltages, but also to reduce losses associated with whatever transient may occur as the currents in 14a and 14b were brought into agreement.

[0041] Fig. 5 shows yet another higher power filter network according to an alternative embodiment of the invention in which a pair of power

transistors 27 and 28 are packaged together (for example, MRF141G transistors from Motorola) and are coupled to low impedance ~~(7 W)~~ (7 Ω) filter networks 29 and 30, and combined with combiner 31 to form a ~~50 W~~ 50 Ω output. Combiner 31 may be constructed from four pieces of ~~12 W~~ 12 Ω semi-rigid coaxial cable and four ferrite balun cores 31a, 31b, 31c, and 31d using techniques well known to those skilled in the art.